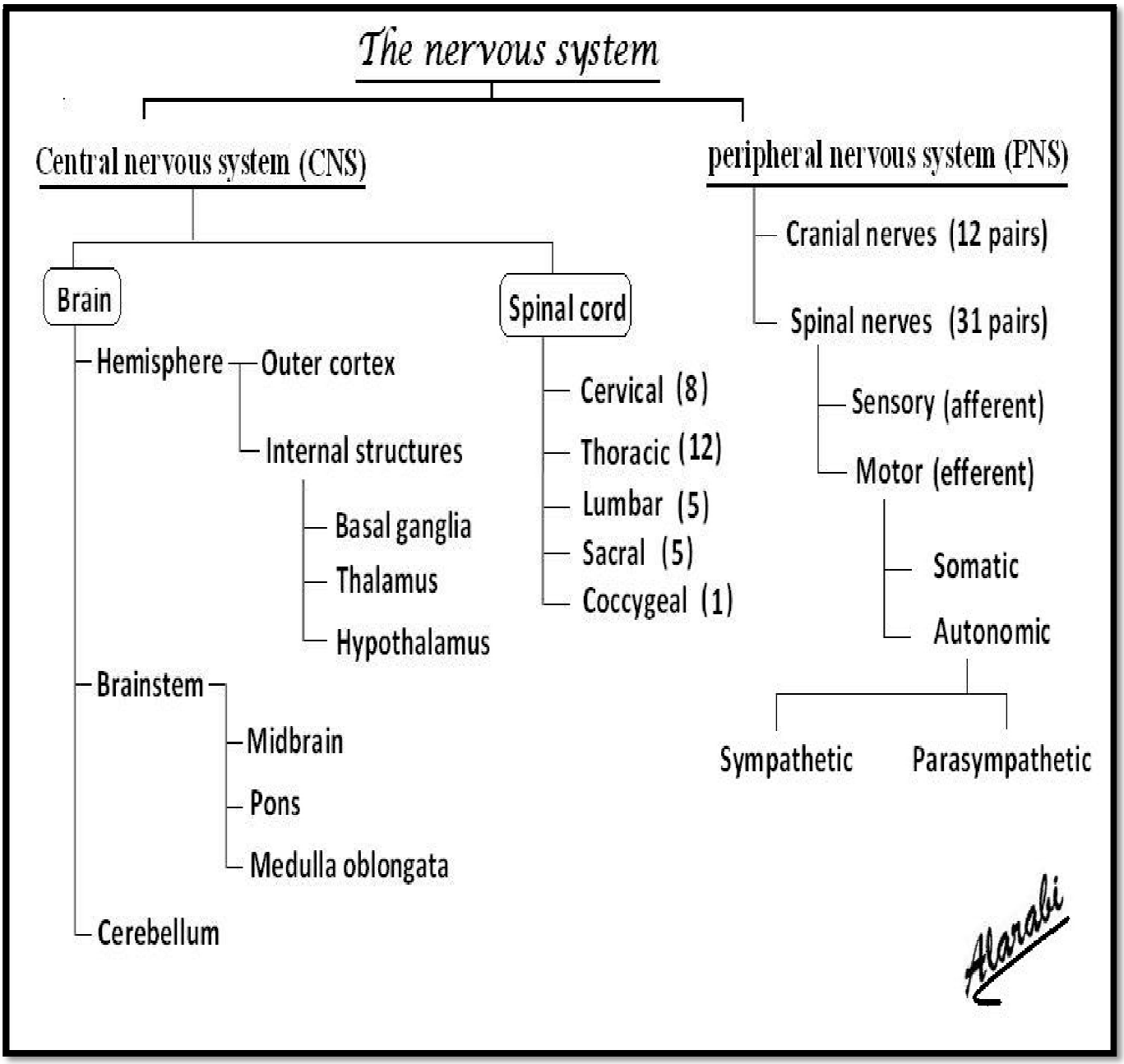
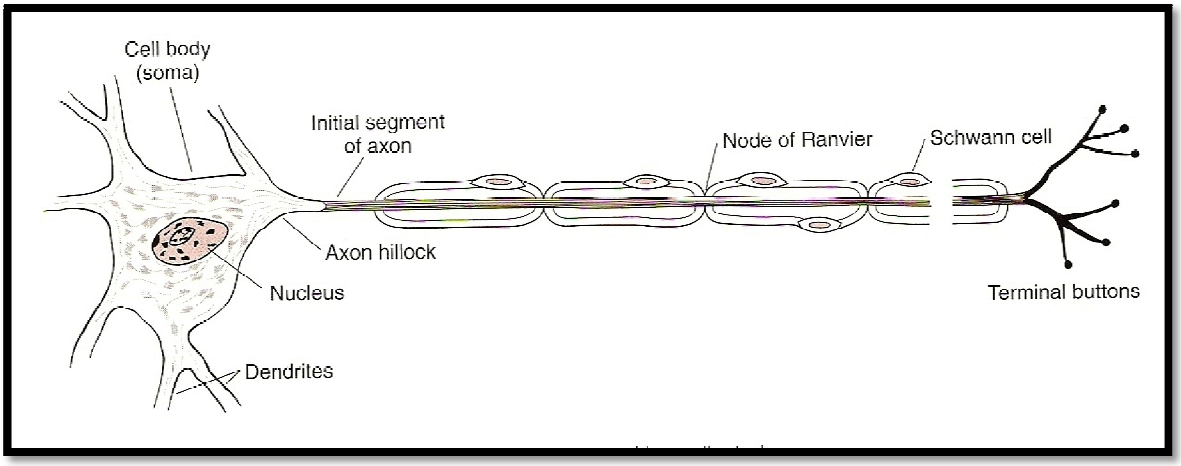
The Autonomic Nervous System



Introduction to the nervous system

The nervous system is composed of an anatomical unit (neuron) and functional unit (reflex).

1] **Neuron**: it is the anatomical (structural) unit of the nervous system. It will be discussed in (Nerve & Muscle) chapter.



2] **Reflex**: it is involuntary action that occurs in response to a stimulus. It is mediated by the reflex arc. The pathway of the reflex arc is composed of:

a- **Receptor**: it is a specialized structure that sensate the changes outside or inside the body.
b- **Afferent** (sensory) neuron: it carries the impulses from the receptors to CNS. Its mother cell is located in the dorsal root ganglia of the spinal nerves.
c- **Center**: it is present in the CNS. It is could be an interneuron or a cell body [e.g. anterior horn cell (AHC) in somatic reflexes].
d- **Efferent** (motor) neuron: it carries the impulse from CNS to the effector organ. Its mother cell is located either in [anterior horn (AH) in case of somatic reflex] or in [lateral horn (LH) in autonomic reflex].
e- **Effector organ**: it is the structure that produces the response

So, the reflex action is classified according to its response into [somatic & autonomic].

	Somatic reflex arc	Autonomic reflex arc
Receptor	The same	
Afferent	The same	
Center	Anterior horn cell (AHC)	Lateral horn cell (LHC)
Efferent	One neuron	Two neurons synapse at ganglia: a- preganglionic: its mother cell in LH. b- postganglionic: its mother cell in ganglia
Effector organ	Skeletal muscle	Smooth ms, cardiac ms, and glands.

The Autonomic Nervous System

It is the part of N.S that controls the involuntary activity of the body. It is divided into two divisions [**sympathetic & parasympathetic**].

Most of the organs innervated by both (symp & parasymp), but there are some organs have only sympathetic innervations [e.g. skin, adrenal medulla, skeletal muscles, blood vessels]. Functionally, there is antagonism between the two divisions (when one stimulate certain organ, the other inhibit it). But sometimes they act in synergism (complementary action) or similarity (doing the same action).

The motor pathway of the ANS differs from the somatic in that the autonomic motor pathway is formed of 2 motor neurons (preganglionic & postganglionic) while the somatic motor pathway that innervates the sk. Muscles is formed of one neuron. The adrenal medulla is innervated by preganglionic sympathetic fiber which is the only exception of the rule.

The preganglionic and postganglionic neurons of both (symp & parasymp) connected (synapsing) at an area called ganglion [the adrenal medulla is considered as ganglia because it is innervated by preganglionic neuron (no postganglionic neuron)]. The ganglion is a collection of nerve cell bodies outside the CNS. It acts as a distributing center (convergence of neurons).

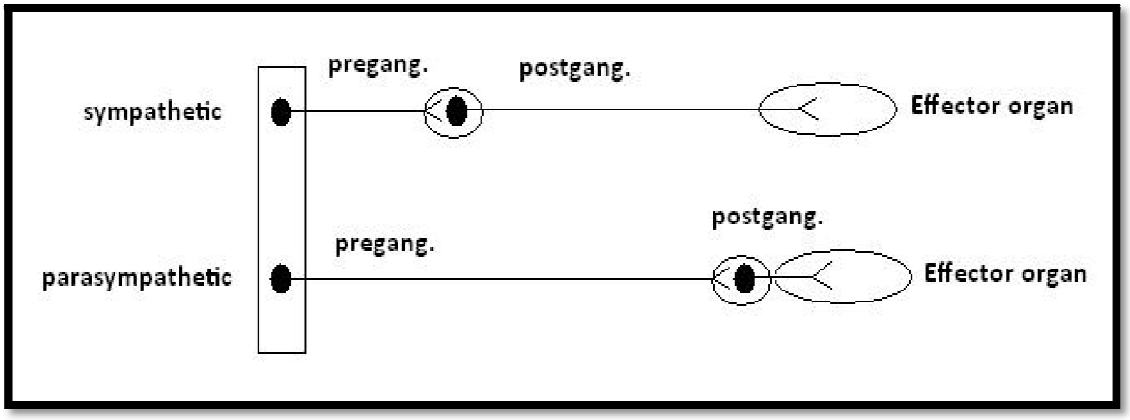
The ganglia are of 3 types:

1- **Lateral** (paravertebral): they are on the sides of vertebral column. They form the sympathetic chain, so they are sympathetic only.

2- **Collateral** (prevertebral): they lie at bifurcation of large arteries. They are mixed sympathetic and parasympathetic.

3- **Terminal**: they lie within the innervated organ. They are only parasympathetic.

Note: as the sympathetic ganglia (lateral) located near the spinal cord, and the parasympathetic ganglia (terminal) located far from the spinal cord; so, the preganglionic neurons are shorter than the postganglionic neurons (in the sympathetic), and longer (in the parasympathetic).



	Sympathetic	**Parasympathetic**
Origin	Thoracolumbar •All the thoracic segments of the spinal cord (T1 – T12). •Upper 3 lumbar segments (L1 – L3).	Craniosacral •Cranial nerves (3, 7, 9, 10) •Middle 3 sacral segments (S2 – S4).
Ganglia	Lateral & collateral	Terminal & collateral
Active during	Stress & emergency (exercise, fear, fight, escape, exam), so it is catabolic.	It is active during rest (relaxation), so it is anabolic.
Activity type	Generalized (mass discharge).	Localized (each part act separately).

The effect of sympathetic & parasympathetic on various tissues

Effect	Sympathetic	Parasympathetic
Eye	• Pupil dilatation (mydriasis). • ↓ Lens power.	• Pupil constriction (miosis). • ↑ Lens power.
Salivary gland	• ↓ saliva (stimulate secretion of viscid saliva).	• ↑ saliva (stimulate secretion of true saliva).
Skin	• Vasoconstriction. • Contraction of piloerector muscle. • Stimulate sweating.	• No known effect.
Heart	• ↑ Heart rate & force of contraction. • Coronary vasodilatation.	• ↓ Heart rate and force of contraction. • Coronary vasoconstriction.
Lung	• Bronchodilataion.	• Bronchoconstriction.
GIT	• ↓ GIT motility & secretion.	• ↑ GIT motility and secretion.
Urinary bladde	•Relaxation of bladder wall. • Contraction of bladder sphincter.	• Contraction of the bladder wall. • Relaxation of bladder sphincter.
Blood vessels	• Vasoconstriction in all vessels except [brain, heart, skeletal muscles].	• Little vasodilator effect.
Adrenal medulla	• Stimulate secretion of Adrenaline and Noradrenaline.	• No effect.
Metabolism	• Hyperglycemic (diabetogenic) effect [inhibit insulin secretion, glycogenolysis, lipolysis, etc].	• Hypoglycemic effect [stimulate insulin secretion].

The neurotransmitters & receptors in the *A.N.S*

	Sympathetic	**Parasympathetic**
Neurotransmitter	The preganglionic fibers are cholinergic. The postganglionic fibers are adrenergic, except that go to the following, which are cholinergic: **a**- Sweat glands. **b**- Smooth muscles of blood vessels.	All the pre and postganglionic fibers are cholinergic.
Receptors **At Ganglia**	Cholinergic (nicotinic) receptors.	Cholinergic (nicotinic) receptors.
At Effector organ	•Adrenergic [α (α1 & α2), & β (β1 & β2)] at most tissues. •Cholinergic (muscarinic) at [sweat glands & smooth muscles of blood vessels].	Cholinergic (muscarinic).

Note: β1 receptors are present only in the heart, α1 cause dilator pupillae ms. and piloerector ms. of the hair.

Mass discharge of the sympathetic N.S

The sympathetic nervous system is usually activated by the hypothalamus all as one unit. This occurs in cases of stress, either mental [e.g. Fear, Exam, embarrassment, etc] or physical [e.g. Exercise, Escape, Fight].

The effects of this mass discharge of the sympathetic prepare the body for these situations. These effects include:

1- Pupil dilatation [to increase the visual field].
2- Bronchodilatation [for hyperventilation to provide more oxygen].
3- Stimulate the adrenal medulla [to provide more adrenaline and noradrenaline to potentiate its effect].

4- ↑ the heart rate and force of contraction [to deliver more blood to the organs that need it].
5- Stimulate glycogenolysis and inhibit insulin secretion [to provide more glucose which is an energy source].
6- ↑ the blood flow to the active areas. This is done by vasoconstriction of the blood vessels in the non active areas [e.g. skin, GIT, bladder, etc] and shifting this blood to the vasodilated vessels of the active areas [e.g. heart, brain, skeletal muscles].

Note: the adrenaline (epinephrine) and noradrenaline (norepinephrine) have similar effect, except that adrenaline is more potent on the heart and metabolism, while noradrenaline is more potent on blood vessels (vasoconstriction).

Horner's syndrome

It is a group of manifestations that results from interruption of the sympathetic supply to the head & neck (the lesion usually at sympathetic chain).
These manifestations include:

[Ptosis – Miosis – Enophthalmos – Anhydrosis – Warm red skin].

The chemical transmitters of the *ANS*

I – **Acetyl choline** (**Ach** or **A.C**):
This neurotransmitter is synthesized at the nerve terminals as the following:

Acetate + Coenzyme A ⟶ Acetyl-CoA.

Acetyl-CoA + Choline ⟶ Acetyl choline + CoA.

After its release and action, the Ach is removed mainly by enzymatic destruction by the ***choline esterase*** enzyme:

$$\text{Acetyl choline} \xrightarrow{\text{Cholinesterase}} \text{choline} + \text{acetic acid}$$

The acetyl choline is released from the nerve terminal (synaptic knobs) of the cholinergic fibers at the following sites:

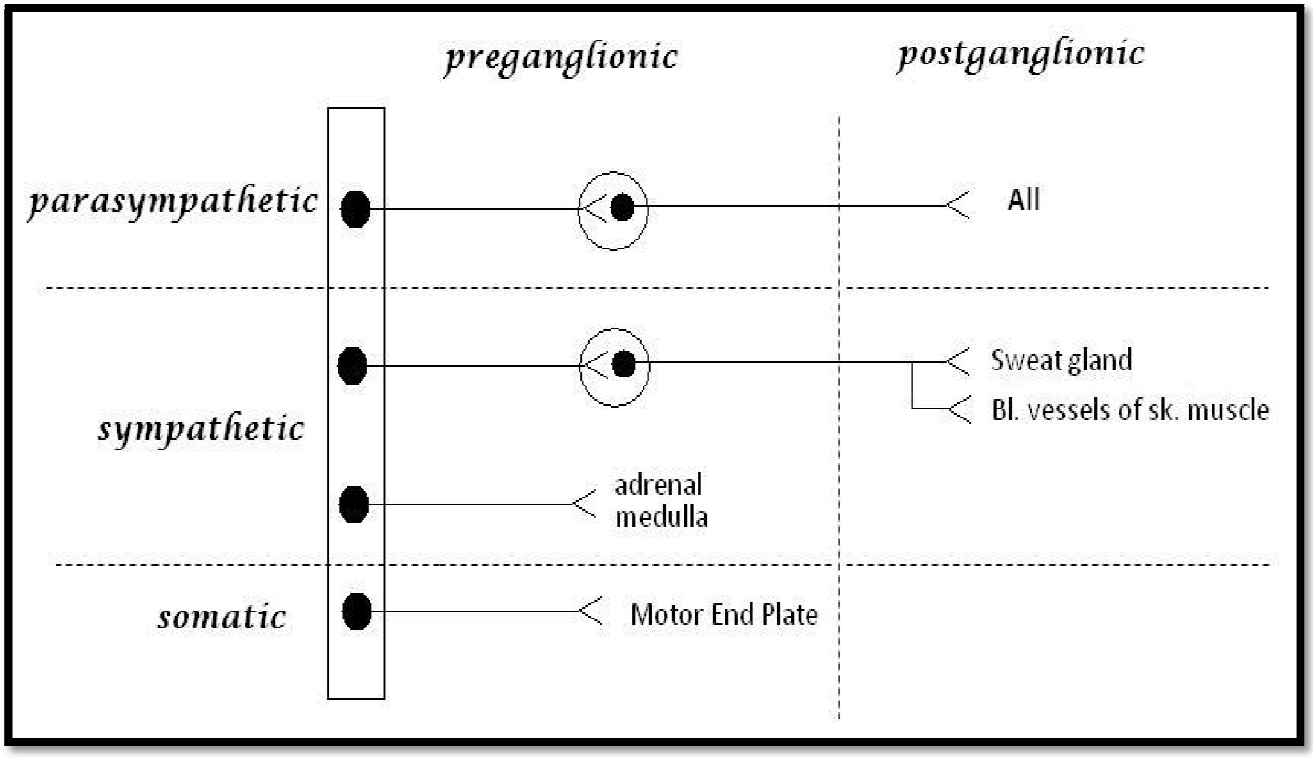
1- Autonomic ganglia of both sympathetic and parasympathetic divisions.

2- All postganglionic parasympathetic fibers.

3- The postganglionic sympathetic fibers that innervate [sweat gland and smooth muscles of blood vessels].

4- The preganglionic sympathetic fibers to the adrenal medulla.

5- The motor end plate at skeletal muscles [somatic not autonomic].



The cholinergic receptor could be affected by administration of drugs. These drugs may:

1- Stimulate the cholinergic receptors. They include:

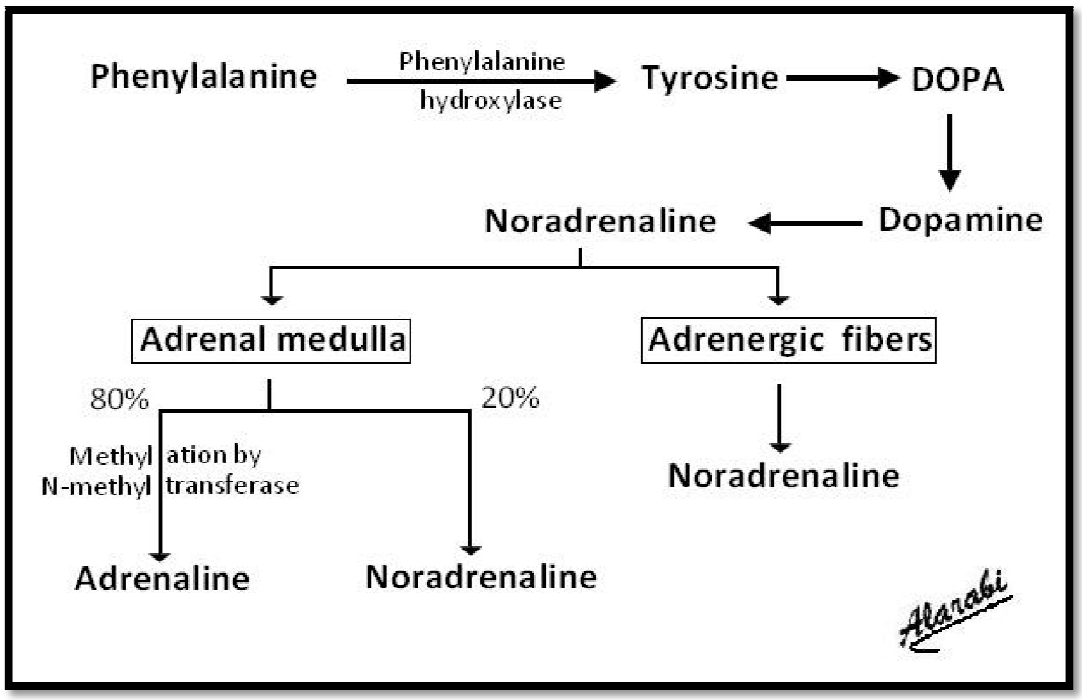
a- Dugs has similar action to Ach [e.g. **Methacholine**, **Pilocarpin**, **Nicotine** (small dose)].
b- Anticholineesterases [e.g. **Neostigmine**, **Prostigmine**].

2- Inhibit the cholinergic receptors. They include:

a- Anticholinergics [e.g. **Atropine**, **Homatropine**].
b- Ganglion blockers [**Hexamethonium**, **Nicotine** (large dose)].
c- Neuromuscular blockers [e.g. **Curare**, **Succinyl choline**].

II – Noradrenaline (norepinephrine) (N.A):

The NT is synthesized at nerve terminal of adrenergic neurons as the following:



In the adrenal medulla, 80% of the noradrenaline converts into adrenaline by the action of ***N-methyl transferase*** enzyme which is not present at nerve terminals, thus adrenaline is formed only in adrenal medulla.

The N.A is removed mainly (50-80 %) by active reuptake to the nerve terminals. The remaining small amount of N.A is removed by:

1- Enzymatic destruction: it is either by:

a- Oxidation: by **monoamine oxidase** enzyme (**MAO**).

b- Methylation: by **catechol-O-methyl transferase** enzyme (**COMT**).

2- Diffusion to surrounding tissues.

The N.A is released from the following sites:

1- All the postganglionic sympathetic fibers [except the 2 cholinergic fibers].

2- The adrenal medulla secretes noradrenaline (20%) and adrenaline (80%).

3- N.A acts as NT inside the CNS.

The adrenergic pharmacology:

Site of action	*Stimulants*	*Inhibitors*
Release of N.A from postganglionic fibers	[Ephedrine - Amphetamine]	[Reserpin – Guanithidine]
Alpha receptors (α)	[N.A – ADR - Phenylephrine]	[Phentolamine – Ergot alkaloids]
Beta receptors (β)	[Isoprenaline - ADR]	[Propranolol]